Missouri Department of Natural Resources
Water Pollution Control Program

Total Maximum Daily Loads (TMDLs)

for

Tributary to Barker Creek
Henry County, Missouri

Submitted December 30, 2003
Approved: February 12, 2004

Two Total Maximum Daily Loads (TMDLs)
For Tributary to Barker Creek
Pollutant: Low pH and Sulfate

November 21, 2003

Name: Tributary to Barker Creek

Location: Henry County near Roseland and Thrush, Missouri

Hydrologic Unit Code (HUC): 10290108-190005

Water Body Identification (WBID): 9000

Missouri Stream Class: The impaired segment unclassified[1]

Beneficial uses: This stream is not classified so no beneficial uses are assigned to it; however, all waterbodies in Missouri are protected by the general criteria (standards) contained in Missouri's Water Quality Standards, 10 CSR 20-7.031(3)(D) and (G).

Size of Impaired Segment: 0.3 mile

Legal Description of Impaired Segment: The upstream end of this segment is in the SE ¼ Section 21, T42N, R24W and the downstream end is in the NE ¼ of Section 28, T42N, R24W

Pollutants: Low pH and sulfate

Pollutant Source: Grey AML

TMDL Priority Ranking: Low

NOTE: There is some disagreement as to the correct name for the creek. "Tributary to Barkers Creek" is the way the entry is worded in the 1998 303(d) list. This stream is an unclassified tributary to "Barkers Creek" listed in Table H—Stream Classifications and Use Designations portion of the Missouri Water Quality Standards. Maps, including the United States Geological Survey Calhoun East 7.5 minute quadrangle map, identify the main creek as "Barker Creek." This document will follow the name given in the USGS maps.

Also, on the 1998 303(d) list the Water Body Identification Number was given as 1211. After that time, Tributary to Barker Creek was determined to be an unclassified stream. In Missouri's WBID numbering system, unclassified streams are denoted beginning with the number 9000, which is the number Tributary to Barker Creek was assigned.

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[1] Unclassified streams do not contain sufficient water during the year to support aquatic life, however they must meet the general criteria and acute toxicity criteria of Tables A and B in the Missouri Water Quality Standards.

1.0 Background and Water Quality Problems

The Tributary to Barker Creek lies between the towns of Thrush and Roseland, close to the eastern border of Henry County, Missouri near Calhoun. This tributary is listed in the 1998 303(d) list as a Class C stream; however, this is incorrect. It is actually unclassified and therefore had no beneficial uses beyond the general criteria assigned to it. The tributary is only one mile long and the impaired segment begins about ¼ mile upstream from its confluence with Barker Creek. A legal description for the upstream and downstream end of the impaired segment is given above.

Barker Creek is a tributary to the Tebo Creek system and has similar impacts from abandoned, underground and strip mines. Underground drift mines[2] were worked in the Barker Creek area from the 1890's to 1930. The small tributary to Barker Creek receives resurfacing acid mine drainage from an underground coal mine. The area also had a gob pile and two collapsed mine openings. Strip mining in the area occurred in the 1950's. Reclamation work undertaken by the landowner was abandoned in 1960 due to the high cost. Reclamation work done by Missouri Department of Natural Resources, Land Reclamation Program on the Grey Abandoned Mine Land next to this tributary in 1993-94 included regrading the area and burying coal wastes. Despite this reclamation work, groundwater seeping through the abandoned mines still contributes acid mine drainage to the creek. The impacted area is presently being used for pasture and wildlife habitat.

Tributary to Barker Creek has been monitored rather infrequently but has consistently poor water quality with red substrate and very low pH and high sulfate measurements. Since this small tributary is unclassified, by definition it has no flow in dry conditions; therefore, there is no upstream flow to dilute the drainage from these abandoned mine lands.

Acid mine drainage forms when sulfide minerals in rocks are exposed to oxidizing conditions. Many types of sulfide minerals occur in nature. Pyrite (fool's gold, a type of iron sulfide) and marcasite (iron sulfide) are minerals common in coal regions. These minerals make up a large amount of the coal wastes in the Barker Creek area. Upon exposure to water and oxygen, sulfide minerals oxidize to form highly acidic (low pH), iron- and high-sulfate drainage. Low pH and high levels of sulfate are harmful to aquatic life.

2.0 Description of the Applicable Water Quality Standards and Numeric Water Quality Target

Beneficial Uses:
Tributary to Barker Creek, WBID 9000, is not classified, so no beneficial uses are assigned to it; however, all waterbodies in Missouri are protected by the general criteria (standards) contained in Missouri's Water Quality Standards, 10 CSR20-7.031 (3). There it states: "No water contaminant, by itself or in combination with other substances, shall prevent the waters of the state from meeting the following conditions." These are the general criteria applicable to this tributary, (3)(D) and (G):

[2] Drift mine – A mine that opens horizontally into a coal bed or coal outcrop. http://www.eia.doe.gov/glossary/glossary_main_page.htm

- Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life.
- Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

Anti-degradation policy:
Missouri's water quality standards include the EPA "three-tiered" approach to anti-degradation, and may be found at 10 CSR 20-7.031(2).

Tier I defines baseline conditions for all waters and it requires that existing beneficial uses are protected. TMDLs would normally be based on this tier, assuring that numeric criteria (such as dissolved oxygen and ammonia) are met to protect uses.

Tier II requires that no degradation of high-quality waters occur unless limited lowering of quality is shown to be necessary for "economic and social development." A clear implementation policy for this tier has not been developed, although if sufficient data on high-quality waters are available, TMDLs could be based on maintaining existing conditions, rather than the minimal Tier I criteria.

Tier III (the most stringent tier) applies to waters designated in the water quality standards as outstanding state and national resource waters; Tier III requires that no degradation under any condition occurs. Management may prohibit discharge or certain polluting activities. TMDLs would need to assure no measurable increase in pollutant loading.

This TMDL will result in the protection of general criteria, which conforms to Missouri's Tier I anti-degradation policy.

Specific Criteria:

pH Standards
Missouri's Water Quality Standards (WQS), 10 CSR 20-7.031 Section (4)(E), states that water contaminants shall not cause pH to be outside of the range of 6.5-9.0 SU.

Sulfate Standards
Sulfate and chloride are linked together in the WQS. 10 CSR 20-7.031 Section (4)(L)1 concerns streams with 7Q10 low flow of less that one cfs. Here it states that the concentration of chloride plus sulfate shall not exceed 1000 milligrams per liter (mg/L) for protection of aquatic life.

Numeric Water Quality Target:

Dry Weather Design Flow: Tributary to Barker Creek (WBID: 9000) is an unclassified stream. Unclassified streams often cease flow in dry periods and do not have designated beneficial uses. The dry weather design flow (7Q10) for Tributary to Barker Creek is 0.0 cfs.

Dry weather design flow from abandoned mine lands can not be accurately determined because surface flow and seepage rates from these areas are variable. Water emerging from the Grey AML areas must maintain water quality sufficient to meet the general criteria found in 10 CSR 20-

7.031(3)(D) and 10 CSR 20-7.031(3)(G) of Missouri's Water Quality Standards during dry weather conditions with little or no upstream dilution.

Because the impairments to Tributary to Barker Creek are in close proximity (< 0.25 mile) to the classified segment of Barker Creek (WBID: 1209), the pH and sulfate toxicity present have a reasonable potential to cause water quality standard violations in the classified waterbody during low-flow conditions. In order to be protective of general criteria in Tributary to Barker Creek and specific criteria in Barker Creek, the applicable water quality criteria will be applied to the unclassified tributary. This approach is reasonable as criteria believed to be protective of aquatic life toxicity in a classified stream should also be protective of general criteria for protection of aquatic life in an unclassified stream.

Numeric Water Quality Target for pH: pH is the expression of hydrogen ion activity in water and is highly dependent on chemical reactions that consume or produce hydrogen ions. In natural waters, these chemical reactions determine the assimilative "buffering" capacity of the solution to neutralize additional acidity or alkalinity. Therefore for TMDL loading purposes, an alkalinity target is also being required to ensure the pH will not be below 6.5 SU in Tributary to Middle Fork Tebo Creek.

Numeric Water Quality Target for Sulfate: Sulfate and chloride criteria for the protection of aquatic life are linked in Missouri's Water Quality Standards. Because Tributary to Barker Creek has a 7Q10 low flow of less than one (1) cubic foot per second, the in-stream concentration of chloride plus sulfate shall not exceed one thousand milligrams per liter (1000 mg/l) at the 7Q10 low flow per 10 CSR 20-7.031(4)(L)1.

3.0 Loading Capacity

The Loading Capacity (LC) is the greatest amount of pollutant loading that a stream can assimilate without becoming impaired. It is equal to the sum of the Load Allocation (LA), the Wasteload Allocation (WLA) and the Margin of Safety (MOS). Since this is a nonpoint pollutant source, no single design flow can be used and thus TMDL targets cannot be mass-based.

pH
For pH as expressed as the concentration in the abandoned mine drainage, the concentration-equivalent load capacity is a pH of 6.5-9.0 SU (the state water quality standard) and a total alkalinity of 35 mg/L or more. To ensure that the pH water quality standard is met and maintained in Tributary to Barker Creek, the alkalinity target is set at 35 mg/L or greater year round.

Sulfate
For sulfate, load capacity is the combined sulfate plus chloride standard of 1000 mg/L. Using the numeric water quality target and margin of safety, an in-stream sulfate plus chloride target of 970 mg/L should ensure that water quality standards are met and maintained in Tributary to Barker Creek.

4.0 Load Allocations (Nonpoint Source Load)

The Load Allocation (LA) is the maximum allowable amount of the pollutant that can be assigned to nonpoint sources. Since the Load Capacity for Tributary to Barker Creek is concentration based, discharges to the stream will be required to meet those concentration targets listed above.

pH

pH is the expression of hydrogen ion activity in water and is highly dependent on chemical reactions that consume or produce hydrogen ions. In natural waters, these chemical reactions determine the assimilative "buffering" capacity of the solution to neutralize additional acidity or alkalinity. Therefore, for TMDL loading purposes, pH will be used to determine the alkalinity required to buffer the acidity present in Tributary to Barker Creek. This will permit the pH in Tributary to Barker to meet and maintain the water quality standard of 6.5 to 9.0 SU.

Sulfate

Using the numeric water quality target and margin of safety, an in-stream sulfate plus chloride target of 970 mg/L should ensure that water quality standards are met and maintained in Tributary to Barker Creek.

5.0 Wasteload Allocation (Point Source Load)

The Wasteload Allocation (WLA) is the maximum allowable amount of the pollutant that can be assigned to point sources. There are presently no point sources discharging to the affected segment of Tributary to Barker Creek; therefore, the mass-WLA is zero for both pH and sulfate. Any future discharges would be required by Missouri State Operating Permit (per the EPA NPDES permit) to maintain a pH in the range of 6.5 – 9.0 SU and concentration of chloride plus sulfate should be 970 mg/L and a secondary requirement for a total alkalinity of 35 mg/L.

6.0 Margin of Safety (MOS)

The pH criterion alone may not provide sufficient assurance that the proper pH range will be maintained in Tributary to Barker Creek due to possible latent acidity. Net alkalinity would be the preferred secondary water quality target, but the lack of sufficient acidity data make this analysis difficult. As a result, in-stream alkalinity will be used as the secondary water quality target. Alkalinity is a measurable characteristic in Tributary to Barker Creek and can be linked to the pH water quality criterion. Alkalinity has units of mg/L as $CaCO_3$ (calcium carbonate) as discussed in Standard Methods for the Examination of Water and Wastewater.

Due to the limited amount of quantifiable alkalinity data for Tributary to Barker Creek, the Ordinary Least Squares (OLS) approach that has been used previously could not be conducted on those data alone. Instead, a regional pH and alkalinity relationship using the OLS approach was constructed using data from water quality studies in the nearby Tebo Creek watershed (Middle Fork Tebo, Tributary Middle Fork Tebo, and East Fork Tebo Creeks). Extrapolation of these data and the results of the regional OLS analysis to Tributary to Barker Creek is reasonable because both watersheds share similar topography and climate and the water quality impairments originate from acidity derived from the same geologic formation.

An Ordinary Least Squares (OLS) approach was used to calculate a regression line (Figure 1) and associated statistics for Tebo Creek watershed (Middle Fork Tebo, Tributary Middle Fork Tebo, and East Fork Tebo Creeks) and Tributary to Barker Creek pH and alkalinity values. Alkalinity standard residuals were computed, plotted, and examined for outliers (Figure 2). Data with standard residual values greater than ± 2.0 were considered outliers and not included in the analysis. The remaining residuals were tested for normality (Figure 3) and found to adhere to a normal distribution. The predicted alkalinity associated with a pH of 6.5, with a confidence interval of 95 percent, would be 22.7 mg/L alkalinity ± 12.7 mg/L alkalinity. Choosing the upper confidence limit of +12.7 mg/L alkalinity as the margin of safety, an in-stream target of 35 mg/L alkalinity (22.7 mg/L + 12.7 mg/L) should ensure adequate buffering to prevent in-stream pH values from dropping below 6.5. To ensure that general criteria and the pH water quality standard are met and maintained in Tributary to Barker Creek, the alkalinity target is set at 35 mg/L or more year round.

Insufficient sulfate, chloride, and other data exist to establish an uncertainty for the linkage between a sulfate plus chloride allocation and water quality in Tributary to Barker Creek. As a result, a margin of safety (MOS) equal to a percent reduction of the loading capacity will be used. Any proposed MOS should include an in-stream allocation for the chloride portion of the combined sulfate plus chloride standard and contributions from other sources. Using the mean chloride concentration found in Tributary to Barker Creek (6.4 mg/L), a conservative in-stream allocation for chloride of one percent (10 mg/L) is appropriate. No other significant sulfate plus chloride sources exist within the watershed, therefore a two percent allocation to account for these uncertainties is reasonable. A margin of safety equal to a three percent reduction of the loading capacity (0.03 * 1000 = 30) has been selected. The sulfate and chloride data used to determine the MOS can be found in Table 2.

Using the numeric water quality target and margin of safety described above, an in-stream sulfate plus chloride target of 970 mg/L (1000 – 30 = 970) should ensure that general criteria and water quality standards are met and maintained in Tributary to Barker Creek.

7.0 Seasonal Variation

The water quality data collected to this point represents all seasons. The primary processes involved in the formation of acid water is not significantly affected by differences in air and water temperatures associated with seasonal change. Missouri standards do not distinguish between summer and winter for pH.

8.0 Monitoring Plan for TMDLs Developed Under the Phased Approach

Barker Creek and Tributary to Barker Creek are scheduled for monitoring two times during the year that monitoring takes place. Measurements will include water temperature, pH and specific conductance and will be used to assess suitability of the water for survival of aquatic life.

9.0 Implementation Plans

Prior reclamation projects in the Tebo Creek area including Tributary to Barker Creek have cost $4.6 million. It is possible that more wetland cells could be constructed to treat underground water

seeps, as has been done in the Middle Tebo Creek area and other abandoned mine land sites around the state. These projects are very expensive, however, and wetland cells would have to be constructed in many locations to handle acidic underground flows. Implementation of any further reclamation work will be addressed as future technology advances are made and program funding allows. This TMDL will be incorporated into Missouri's Water Quality Management Plan.

10.0 Reasonable Assurances

The department's Water Pollution Control Program will continue low-flow water chemical monitoring of the impaired segments of the Tebo Creek system. Periodic review of the department's Water Quality Management Plans and monitoring data should provide reasonable assurance that Tributary to Barker Creek will meet water quality standards.

11.0 Public Participation

The water quality limited segments of Tributary to Barker Creek are included on the approved 1998 303(d) list for Missouri. The Missouri Department of Natural Resources, Division of Environmental Quality, Water Pollution Control Program developed these TMDLs. Six public meetings to allow input from the public on impaired waters were held between August 18 and September 22, 1999. No comments pertaining to Tributary to Barker Creek were received during the public meetings. A presentation on the Tebo Creeks TMDL was given April 7, 2002 to the Henry County Soil Conservation District Board. In this meeting, general facts about the Clean Water Act, the TMDL component of the Act, and the purpose of the Tributary to Barker Creek TMDL were explained.

Tributary to Barker Creek TMDL was placed on public notice from November 21, 2003 to December 21, 2003. One public comment was received and the document was adjusted appropriately.

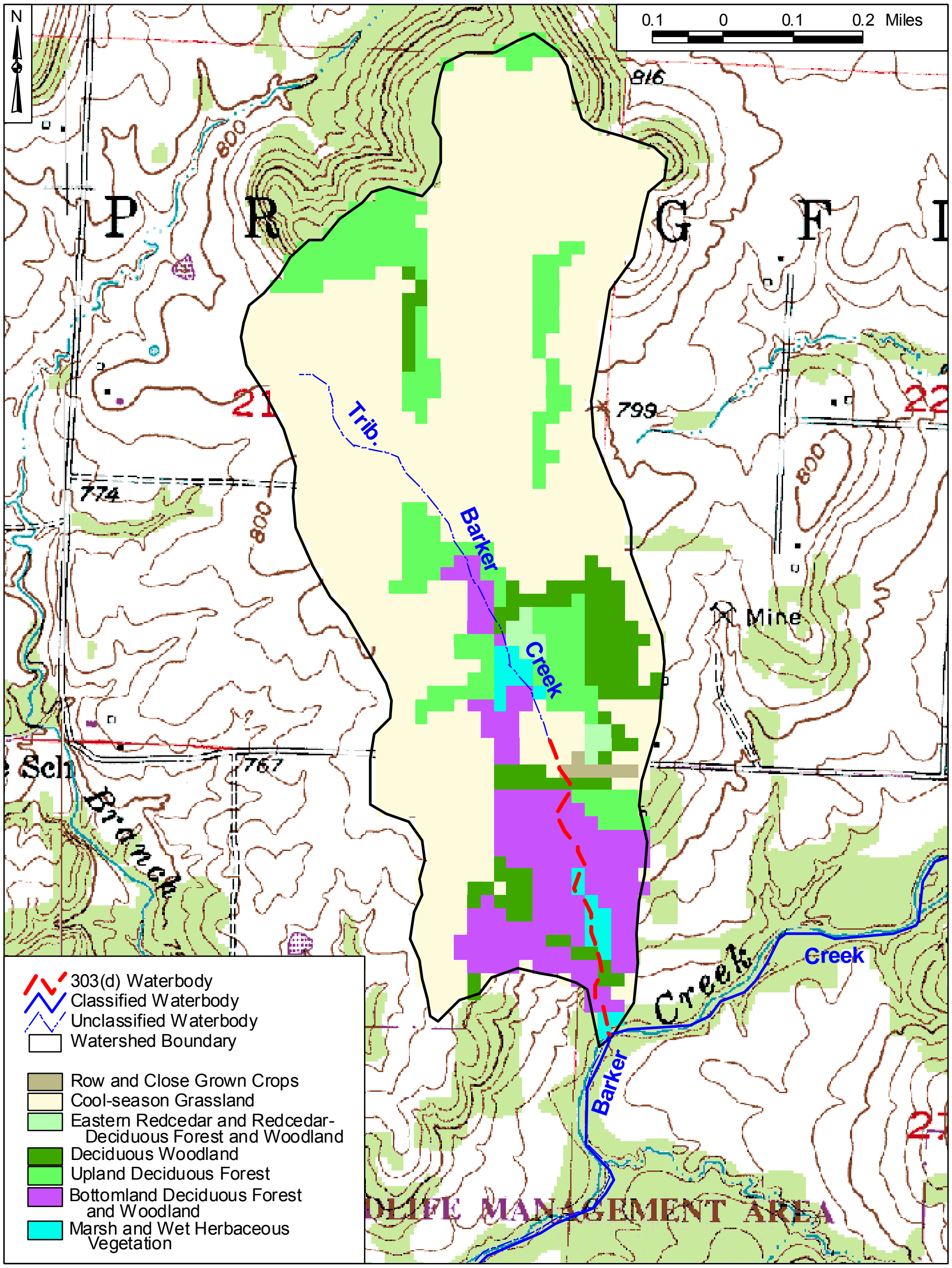
12.0 Appendices and List of Documents on File with MDNR

Appendix A – Land Use
Appendix B – Location Map
Appendix C – Data

Documents on file with MDNR:

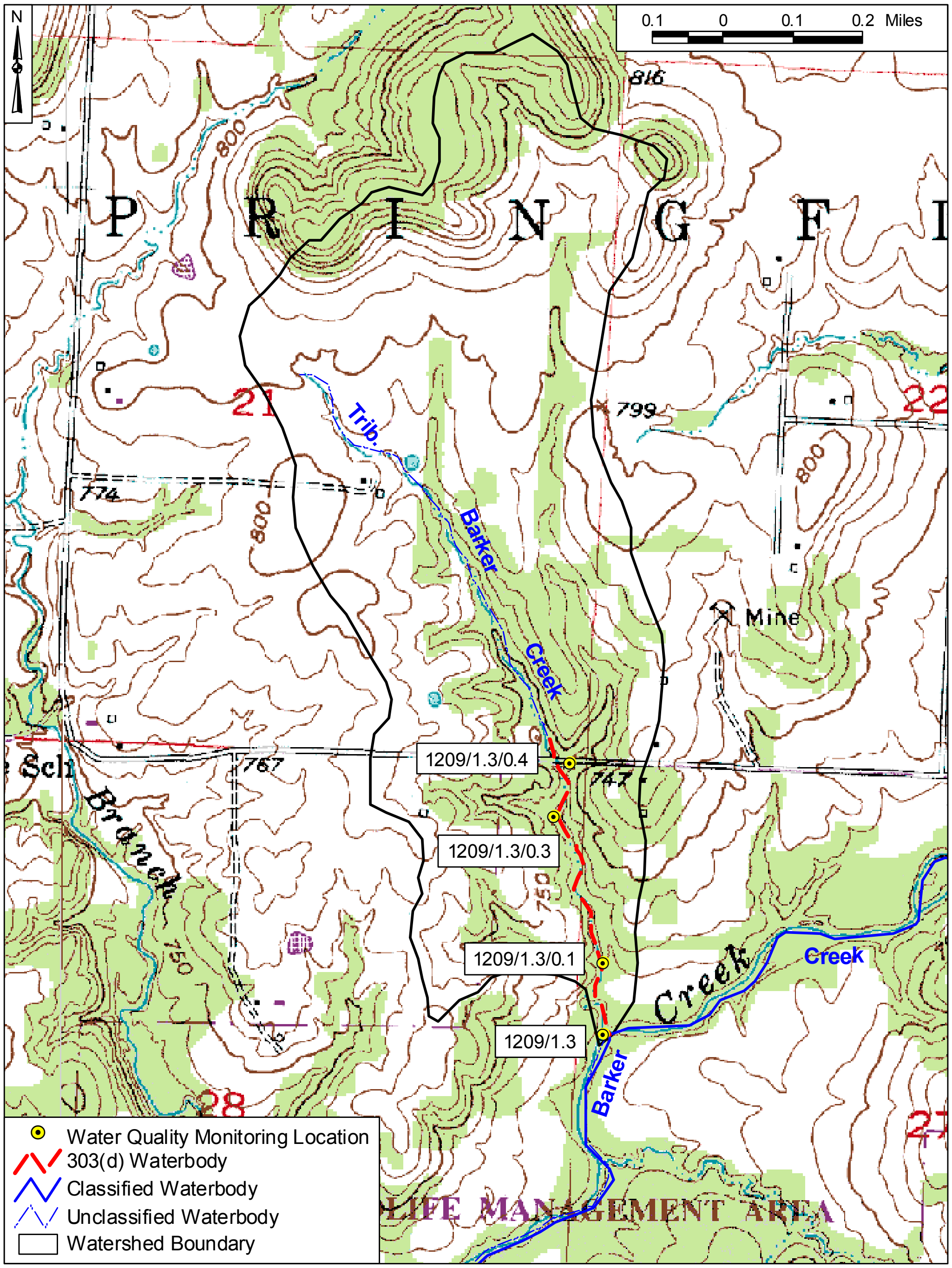
Public notice announcement
Public comments
MDNR's response to public comments

Appendix A
Land Use



CLASS_LABEL	Area (acres)
Urban Impervious	0.00
Urban Vegetated	0.00
Barren or Sparsely Vegetated	0.00
Row and Close Grown Crops	1.56
Cool-season Grassland	222.39
Warm Season Grassland	0.00
Glade Complex	0.00
Eastern Redcedar and Redcedar-Deciduous Forest and Woodland	2.89
Deciduous Woodland	22.46
Upland Deciduous Forest	45.14
Shortleaf Pine-Oak Forest and Woodland	0.00
Shortleaf Pine Forest and Woodland	0.00
Bottomland Deciduous Forest and Woodland	37.36
Swamp	0.00
Marsh and Wet Herbaceous Vegetation	5.34
Open Water	0.00
Total	**337.14**

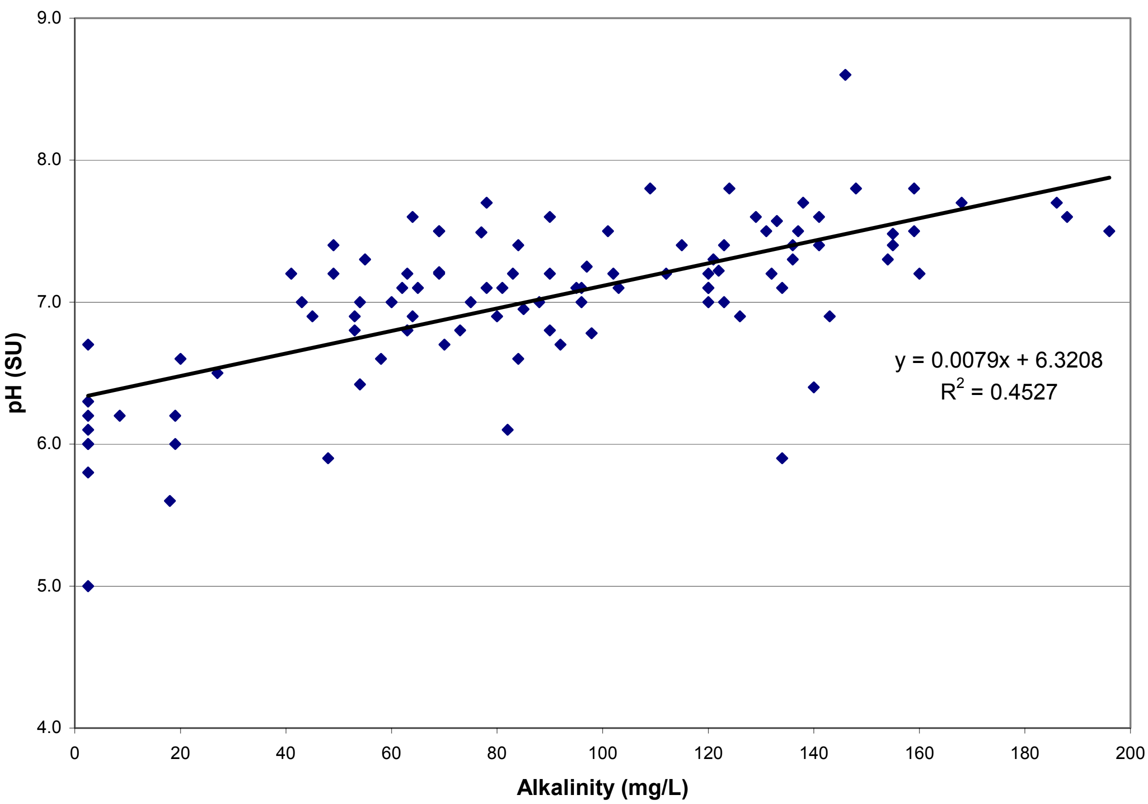
Appendix B
Location Map Showing Impaired Segment



Appendix C: Data

Figure 1. Relationship between regional pH and Alkalinity for Tributary to Barker Creek, Henry County, Missouri

Due to the limited amount of quantifiable alkalinity data for Tributary to Barker Creek, a regional pH and alkalinity relationship was constructed using data from water quality studies in the nearby Tebo Creek watershed (Middle Fork Tebo, Tributary Middle Fork Tebo, and East Fork Tebo Creeks). Extrapolation of these data and the results of the regional OLS analysis to Tributary to Barker Creek is reasonable because both watersheds share similar topography and climate and the water quality impairments originate from acidity derived from the same geologic formation.



Regression Analysis

Mean pH	7.031
Mean Alkalinity	89.470
Sum of Squares (x^2 = Alkalinity)	232600.108
Sum of Squares (y^2 = pH)	32.360
Sum of Squares (xy = Alkalinity and pH)	1845.851
Pearson Correlation Coefficient	0.673
Regression Slope	0.0079
Mean Square Error	0.175
Standard Error of the Regression	0.419

Regression Statistics	
Multiple R	0.672800644
R Square	0.452660706
Adjusted R Square	0.447241505
Standard Error	0.418767345
Observations	103

Ordinary Least Squares (OLS) Analysis
Tributary to Barker Creek, Henry County, Missouri

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	14.64816286	14.64816286	83.52905023	7.04398E-15
Residual	101	17.711975	0.175366089		
Total	102	32.36013786			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	6.320768747	0.087964451	71.85594467	1.56118E-88	6.146270962	6.495266532
X Variable 1	0.007935725	0.000868296	9.139422861	7.04398E-15	0.00621326	0.009658191

Figure 2. Alkalinity Residual Plot for OLS Analysis, Tributary to Barker Creek, Henry County, Missouri

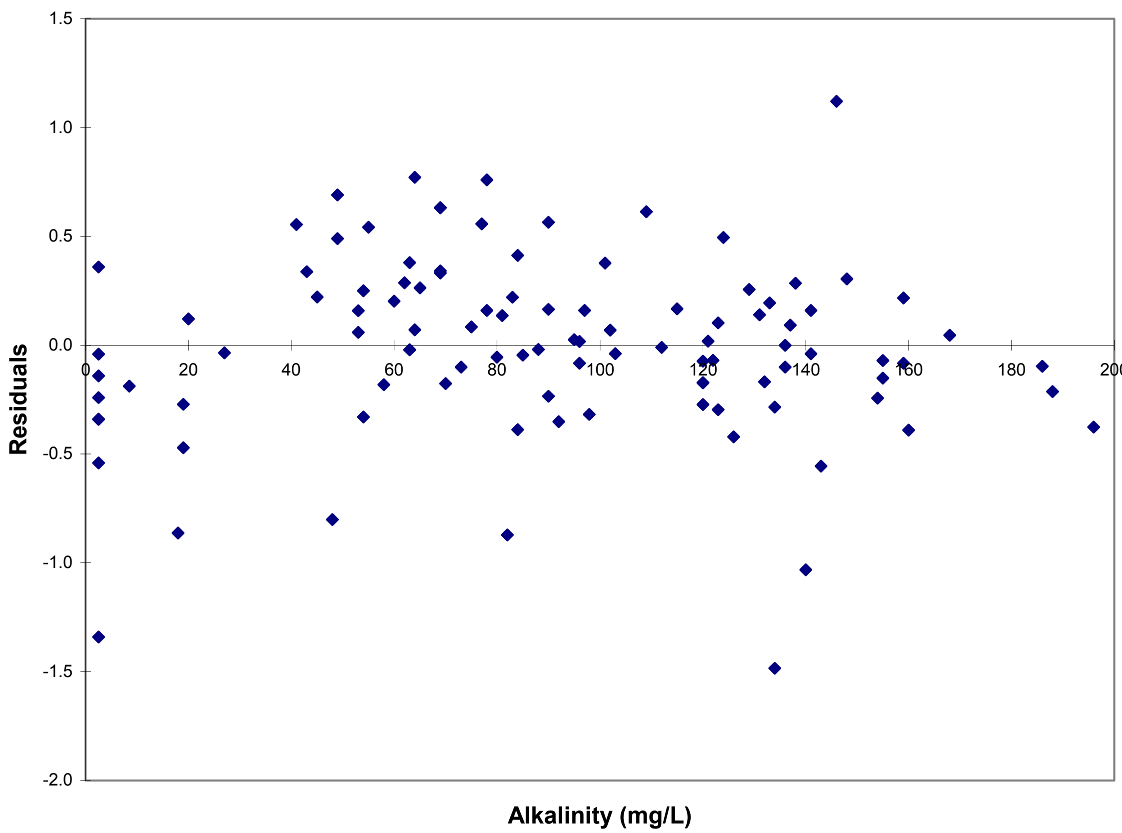


Figure 3. Normality Plot for Tributary to Barker Creek, Henry County, Missouri

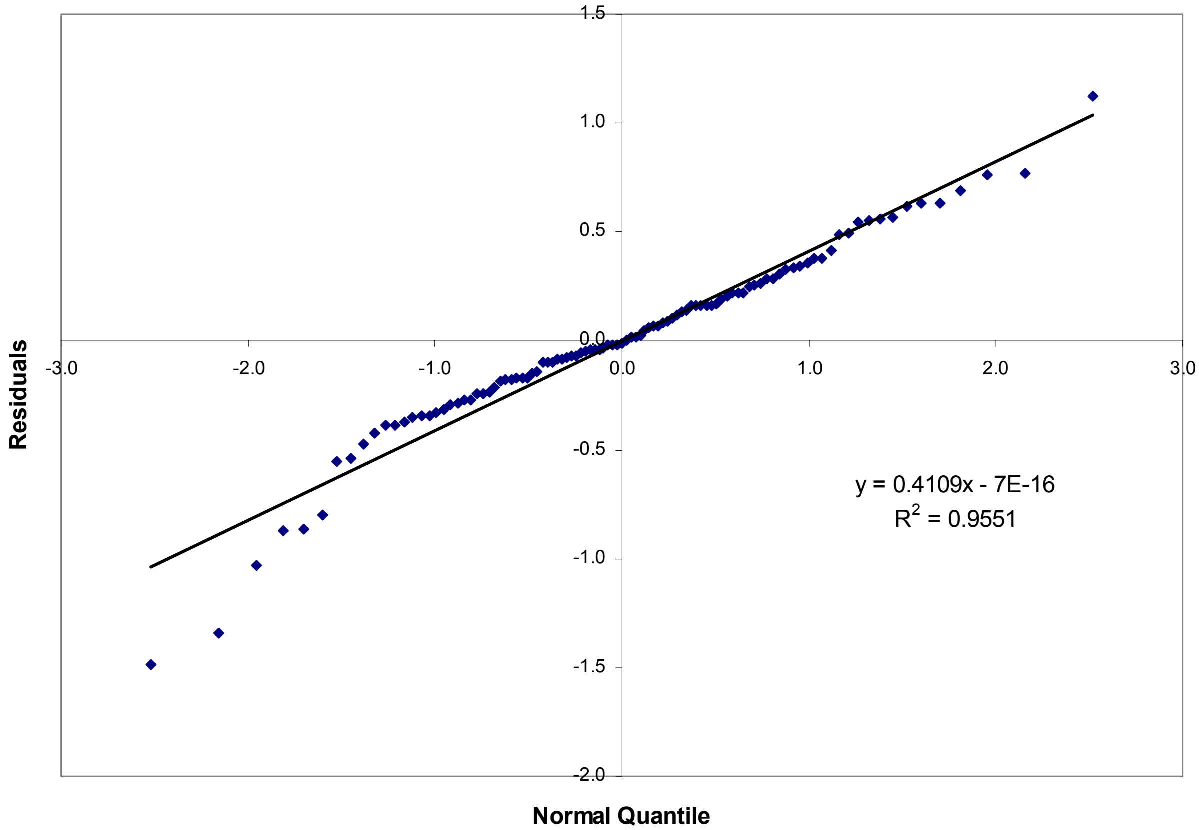


Table 1. Tributary to Barker Creek Regional Post-Reclamation Data

Site	Site Name	Yr	Mo	Dy	pH	Alk
1209/1.3	Barker Cr. Just DS of confluence with trib.	2001	8	16	5.6	18
1209/1.3	Barker Cr. Just DS of confluence with trib.	2001	10	4	6.7	70
1209/1.3/0.1	Trib. To Barker Cr. nr. Mouth	2001	6	19	6.0	19
1209/1.3/0.1	Trib. To Barker Cr. nr. Mouth	2002	6	6	6.4	54
1209/1.3/0.3	Trib. to Barker Cr. 75 yds. bl. CR NE 300	2003	4	24	6.3	2.499
1209/1.3/0.3	Trib. to Barker Cr. 75 yds. bl. CR NE 300	2003	6	10	6.2	2.499
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	2003	4	24	6.0	2.499
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	2003	6	10	6.0	2.499
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	1997	7	2	7.0	96
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	1997	7	30	6.9	143
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	1998	8	11	7.0	85
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	1998	9	3	6.8	90
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2000	3	21	7.0	54
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2000	6	7	7.0	88
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2000	9	12	6.8	63
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2000	9	12	6.8	63
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2001	4	26	6.7	92
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2001	6	19	7.1	95
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2001	8	14	7.4	115
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2001	8	16	7.2	112

Table 1 (cont). Tributary to Barker Creek Regional Post-Reclamation Data

Site	Site Name	Yr	Mo	Dy	pH	Alk
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2001	9	12	6.6	84
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2001	10	4	7.1	78
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2001	11	27	7.1	96
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2001	12	5	7.0	123
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2002	1	10	6.9	80
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2002	3	14	7.7	78
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2002	6	6	7.4	84
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2002	6	20	7.2	90
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2002	10	3	7.5	69
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2003	4	24	6.8	53
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	2003	6	10	6.4	140
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	1998	8	11	7.5	101
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	1998	9	3	7.3	97
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2000	3	21	6.9	45
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2000	6	7	7.1	103
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2000	9	12	7.1	120
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2000	9	12	7.1	120
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2001	4	26	7.0	75
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2001	6	19	7.1	65
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2001	8	14	7.3	136
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2001	8	16	7.4	123
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2001	9	12	6.9	126
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2001	10	4	7.2	120
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2001	11	27	7.8	148
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2001	12	5	7.3	121
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2002	1	10	7.4	136
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2002	3	14	7.6	64
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2002	6	6	7.5	77
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2002	6	20	7.6	90
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2002	10	2	7.2	160
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2003	4	24	7.2	49
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	2003	6	10	7.4	141
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	1997	7	2	6.8	73
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	1997	7	30	6.9	53
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	1998	4	21	7.2	102
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	1998	8	11	7.2	41
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	1998	8	11	7.7	168
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	1998	9	3	7.0	43
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	1999	7	21	6.6	58
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2000	3	9	7.6	129
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2000	3	21	7.1	62
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2000	6	15	7.2	63
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2000	6	20	7.4	49
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	3	7	6.9	64
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	4	26	7.0	60
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	6	13	7.2	83
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	6	26	7.1	81
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	8	14	6.5	27
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	8	16	6.2	19
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	9	6	5.8	2.499
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	9	7	7.2	132

Table 1 (cont). Tributary to Barker Creek Regional Post-Reclamation Data

Site	Site Name	Yr	Mo	Dy	pH	Alk
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	10	3	5.0	2.499
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	11	27	6.2	9
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	11	30	6.7	2.499
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2001	12	14	5.9	134
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2002	1	10	6.1	2.499
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2002	3	14	7.3	55
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2002	3	20	7.8	124
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2002	6	6	7.2	69
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2002	6	6	7.6	133
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2002	6	20	7.2	69
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2003	4	23	6.6	20
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1mi.bl. AML	2003	6	10	5.9	48
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2000	3	21	7.7	138
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2000	6	15	7.8	159
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2000	9	21	7.5	159
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2001	4	26	7.6	141
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2001	6	19	7.3	154
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2001	8	14	8.6	146
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2001	9	6	7.1	134
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2001	10	3	7.8	109
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2001	11	27	7.6	188
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2001	11	30	7.7	186
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2002	1	10	7.0	120
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2002	3	14	7.4	155
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2002	6	6	7.5	155
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2002	6	20	7.5	196
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2002	10	2	7.5	131
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2003	4	24	7.5	69
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	2003	6	10	7.5	137
1288/3.5	Trib. M.Fk.Tebo within AML	2002	12	10	6.1	82
1288/3.5	Trib. M.Fk.Tebo within AML	2003	3	3	6.8	98
1288/3.5	Trib. M.Fk.Tebo within AML	2003	6	5	7.2	122
Note: Values of 2.499 represent a lab reported value of “less than 5” as the analysis result						
pH in Standard Units, Alkalinity in mg/L as $CaCO_3$						

Site	Site Name	Latitude	Longitude	Description
1209/1.3	Barker Cr. Just DS of confluence with trib.	38.39919	-93.56928	Hike in point @ SWNW Sec.27,T42N,R24W
1209/1.3/0.1	Trib. To Barker Cr. nr. Mouth	38.40067	-93.56928	Trib. To Barker Cr.@NWSWNW Sec.27,42,24W
1209/1.3/0.3	Trib. to Barker Cr. 75 yds. bl. CR NE 300	38.40370	-93.57060	Trib. to Barker Cr. @SENENE Sec.28,T42N,R24W
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	38.40480	-93.57020	Trib. 50 yds.south of county rd.@NENENE Sec.28
1282/10.4	E. Fk. Tebo Cr. 0.5 mi.bl. Triple AML	38.54370	-93.54090	E. Fk. Tebo Cr. @ Hwy 2, SWSW Sec.35, 44N,24W
1282/11.1/0.4	Trib. to E. Fk. Tebo Cr. 0.5mi.ab. Triple AML	38.55680	-93.53740	Trib. to E. Fk. Tebo Cr. @ road in NWNWNE Sec.35, 44N,24W
1288/1.5	Trib. M. Fk. Tebo Cr. 0.1 mi.bl. AML	38.51870	-93.61170	Trib. M Fk. Tebo Cr. @ Hwy 2, SE Sec. 36, 44N, 25W
1288/2.3/1.7	Trib. M. Fk. Tebo Cr. 0.1mi.ab. AML	38.57110	-93.64330	Trib. M.F. Tebo Cr.@NE Sec. 26, 44N,25W
1288/3.5	Trib. M.Fk.Tebo within AML	38.54469	-93.62759	36 T44N R25W @HWY2 crossing

Table 2. Tributary to Barker Creek Post-Reclamation Sulfate and Chloride Data

Site	Site Name	Yr	Mo	Dy	SO4	Cl	SO4 + Cl
1209/1.3	Barker Cr. Just DS of confluence with trib.	2001	8	16	129	2.499	131
1209/1.3	Barker Cr. Just DS of confluence with trib.	2001	10	4	33	9	42
1209/1.3	Barker Cr. Just DS of confluence with trib.	2002	10	3	66	10	76
1209/1.3/0.1	Trib. To Barker Cr. nr. Mouth	2001	8	14	1190	5	1195
1209/1.3/0.1	Trib. To Barker Cr. nr. Mouth	2001	6	19	114	4.99	119
1209/1.3/0.1	Trib. To Barker Cr. nr. Mouth	2002	6	6	79.5	16.8	96
1209/1.3/0.3	Trib. to Barker Cr. 75 yds. bl. CR NE 300	2003	6	10	584	5	589
1209/1.3/0.3	Trib. to Barker Cr. 75 yds. bl. CR NE 300	2003	4	24	257	6	263
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	2001	9	12	938	2.499	940
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	2001	10	4	1070	2.499	1072
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	2001	11	27	1090	8.09	1098
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	2002	10	3	800	5	805
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	2002	6	6	452	5.89	458
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	2003	4	24	255	7	262
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	2003	6	10	686	6	692
Note: Values of 2.499 represent a lab reported value of “less than 5” as the analysis result							
Sulfate (SO4) and chloride (Cl) concentrations are in mg/L							

Site	Site Name	Latitude	Longitude	Description
1209/1.3	Barker Cr. Just DS of confluence with trib.	38.39919	-93.56928	Hike in point @ SWNW Sec.27,T42N,R24W
1209/1.3/0.1	Trib. To Barker Cr. nr. Mouth	38.40067	-93.56928	Trib. To Barker Cr.@NWSWNW Sec.27,42,24W
1209/1.3/0.3	Trib. to Barker Cr. 75 yds. bl. CR NE 300	38.40370	-93.57060	Trib. to Barker Cr. @SENENE Sec.28,T42N,R24W
1209/1.3/0.4	Trib. To Barker Cr. nr. Road	38.40480	-93.57020	Trib. 50 yds.south of county rd.@NENENE Sec.28